2005 PROGRESS REPORT

Riparian Willow Restoration along the Illinois River at Arapaho NWR, Colorado
SSP03R603

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BACKGROUND

This is an internal progress report. Data and discussion are preliminary and should not be used or disseminated as formal USGS results.

Riparian willow communities along the Illinois River at Arapaho NWR provide important habitat for a number of wildlife species, including neotropical migratory birds. Existing stands are sparse and discontinuous throughout much of the Refuge and appear overaged, with little natural regeneration. Likely causes include historical clearing; reduced streamflow from water diversion; channel incision perhaps related to diminished sediment supply; possible climatic shifts; and high levels of herbivory from cattle, introduced moose, and elk, which have recently increased densities and altered distributions.

The FWS Comprehensive Conservation Plan for Arapaho NWR states the goal to:

> *Provide a riparian community representative of the historic flora and fauna in a high valley of the central Rocky Mountains to provide habitat for migratory birds, large mammals, and river dependent species.*

The plan further specifies the objective to:

> *Restore 50 to 100 acres of dense (40-100% canopy closure) willow in patches >0.2 ha and >10 m wide in the central third of the Illinois River (from the north end of the island to the confluence with Spring Creek) to connect existing willow patches and maintain 535 acres of dense willow in patches in the lower third of the Illinois River to benefit neotropical migrant songbirds (yellow warbler, willow flycatcher) and resident moose and beaver.*

The overall goal of the FWS-USGS study is to inform these restoration activities by quantifying the effects of alternative management actions on riparian willow communities in order to provide the Refuge with a set of management tools with known effectiveness under different circumstances. There are three major components:

(1) A **core exclosure experiment** focused on herbivory release of willows with moisture (depth to water) as a co-variate;
(2) A series of **restoration tests** aimed at identifying efficient restoration procedures and identifying constraints on successful restoration; and
(3) **Contextual analyses** aimed at understanding the status and dynamics of willow in the valley as a whole and how the Refuge willow communities fit into a larger picture.

CORE EXCLOSURE EXPERIMENT

Paired exclosures and controls (5 sets) were established in the northern portion of the Refuge in 2003 (Fig. 1). They were initially sampled for willow cover by species and height class at the end of the growing season in 2003. We anticipate a resampling for the herbivory release response in Sept., 2006 – encompassing 3 winters (when most herbivory occurs) and 3 growing seasons. If limited elk hunting is initiated in the fall of 2006, this would also represent a 3-year "high elk herbivory" interval for comparison with later lower-herbivory periods influenced by elk-hunting effects on density or movement patterns. Incidental observations of individual plants suggest the exclosures are beginning to produce greater net shoot growth, especially a height growth of suppressed individuals less than 1.5 m tall (Fig. 2).

We installed staff gages and recorded water levels at the staff gages and wells (5/site) at roughly 2-week intervals from May-October in both 2004 and 2005. We also installed continuous (every 30 minutes) level recorders in one stream stilling well at each of the sites to track surface water changes. The record of average daily stage from the stream recorder, along with episodic well measurements from the bank well at site C, is presented in Figure 3. 2004 was a dry year, whereas 2005 was wet relative to the last 10 years with extensive overbank inundation of the bottomland in early to mid June.

The ranges of water levels at the wells and staff gages in 2004 and 2005 are superimposed on the channel cross sectional geometry for each of the sites in Figure 4. High water was estimated as the maximum stage from the recorder because we were not able to access the sites for manual well measurements at the time of "maximum stage." The 2005 overbank period did a lot of damage to staff gages and exclosure fencing (Fig. 5); redistributed a lot of large woody debris; stimulated substantial growth of meadow vegetation, willow leaders, and mosquitoes; produced some undercutting of banks -- but did not create appreciable areas of new bare ground that might be suitable for willow seedling recruitment.

We began, but have not completed, surveying to develop a digital terrain model (topographic map) of each of the sites. Cross sectional geometry of Figure 4 is based on a single, relatively crude survey at the well locations.

RESTORATION TESTS

These are tests at several levels involving specific, replicated experiments and also trying different equipment and administrative arrangements that might be employed in broader scale restoration.

2004 plantings. These involved a quantitative experiment at the exclosure-control sites and a more free-form set of activities below the overlook in the northern end of the Refuge. Both employed volunteers under a three-way Memorandum of Understanding and cooperative relationship among USGS, FWS, and Wildlands Restoration Volunteers (WRV), a non-profit organization based in Boulder, CO. WRV provided more than 40 volunteers for the main planting weekend in late May, harvesting freshly cut poles and doing the planting in both the quantitative experiment described below and in a free-form site trying a variety of planting procedures (poles in excavated holes, willow stakes driven into the channel bed and bank, and mats of willow cuttings). Qualitative results from this free-form area included (a) pole-planting responses similar to those of the quantitative experiment described below; (b) no survivorship at high terrace transect locations, (c) no survivorship of horizontal mat plantings; (d) moderate survivorship of stake material used by itself or to secure bundles. Exploratory examination of mycorrhizal colonization rates of several of these planted *S. monticola* poles along with some similar sized naturally established short willow indicated relatively low levels of colonization (Table 1). Sample size was very low, but only a *S. geyeriana* individual had moderately high levels of colonization. Less than 10% of root locations were colonized in either natural or planted *S. monticola*.

The 2004 quantitative experiment used *Salix lasiandra* (whiplash willow) pole cuttings. *S. lasiandra* is the largest of the common willows at Arapaho NWR. One quarter of each plot (both exclosure and control) at each of the 5 sites was used for the manipulations. Each manipulation subplot was divided into 3 zones: terrace or upland; near-bank (within 10 meters of bank-full lip); and channel (below bank-full lip). Two kinds of *S. lasiandra* poles were used as a plant-type treatment: (a) fresh-cut in late-May at the time of planting about 2 weeks after bud-break; and (b) pre-cut about 2 weeks before bud-break. The pre-cut poles were stored at a State Forest facility in the mountains in a snowbank. Eight individuals of each type of pole were placed in 1-m holes excavated with a 6-inch auger mounted on a tracked-Bobcat (T190) in the terrace and near-bank zones. In the channel zone, 8 bundles of each type of willow poles (3 poles/bundle) were staked in vertical trenches dug into the side of the bank.

Essentially all these planted materials vigorously leafed out within the first month (Fig. 6). There was substantial die-back in the drier August period of the first year. Overall survivorship at the end of the second growing season (September 2005 for May 2004 plantings) was about 11% (Fig. 7) with an average longest-leader length of survivors of 41 cm. There was no effect of harvest date: before budbreak pre-havesting had survivorship of 11.6% and mean leader length of 41.4 cm (survivors), and harvesting at time of planting (post budbreak) had survivorship of 11.1% and mean leader length of 40.5 cm (survivors).

2005 plantings. WRV provided 50 volunteers the weekend of June 11, 2005, to implement willow pole planting. Unfortunately, no work was completed because the bottomland was inaccessible due to overbank flooding (Fig. 5) and heavy snowfall on June 10 (Fig. 8). We conducted limited pole planting of *Salix exigua* and *S. geyeriana* at 4 off-channel depression sites in late June. We used a hydraulic "stinger" constructed from ¾ inch pipe powered by a portable pump using stream water to hydraulically "drill" a narrow 1-m deep hole for each pole. These were sampled at the end of the first growing season (Sept. 2005). Compared to the 2-year old 2004 plantings, the 1-year old 2005 plantings had somewhat higher survivorship, shorter leader lengths of survivors, and a strong species effect. Survivorship was 28% for *S. exigua* and 15% for *S. geyeriana.* Leader lengths of survivors were 9.7 cm for *S. exigua* and 4 cm for *S. geyeriana.*

Operational experience. The volunteer arrangement worked well for those aspects of the overall job that are labor-intensive and do not require a sequence of actions over multiple days or weeks. There are some administrative costs associated with organizing and supporting this number of people and some timing constraints and risks, especially in the case of inclement weather as we experienced in 2005. Integral use of volunteers over multiple years does (a) build a Refuge constituency and (b) may be the most feasible way of accomplishing widespread direct alteration of riparian vegetation at Arapaho, given budget realities.

Both the tracked Bobcat (T190) with 6" auger and hydraulic "stinger" were practical and effective for 1-1.5 m pole planting. The Bobcat (a) had rental costs, (b) required a trailer towed by a heavy-duty pickup to get close (road) to the sites, (c) required at least a semi-skilled operator, and (d) required hand-filling of augered holes. The hydraulic "stinger" (a) required close proximity to a legal water source (b) often left a gap between the walls of the narrow hole and the planted stem, and (c) was awkward to move any substantial distance along the bank (hand carrying pump and hoses).

CONTEXTUAL ANALYSES

Again in 2005, we de-emphasized work at broader scales to concentrate on those long-term study elements that will take years to see meaningful responses. There are some relevant, general results emerging from work at other mountain valley bottom willow systems with low beaver populations and elevated levels of herbivory from protected elk populations (most notably Yellowstone and Rocky Mountain National Parks). The emerging view involves multiple interacting factors with at least two semi-stable system conditions. One condition is a meadow with (a) high levels of ungulate herbivory (elk, but possibly also cattle and moose) keeping willow in a shrub growth form (30-80 cm tall); (b) low densities of beaver and beaver ponds in the absence of a tall willow beaver food supply; (c) limited fluvial disturbance from overbank flooding or lateral channel movement creating new, bare surfaces for willow seedling establishment; and (d) a bottomland that is generally drier than optimum for willow, possibly in combination with channel incision.

Another condition is a willow-dominated bottomland with (a) high densities of beaver and beaver ponds; (b) tall willows that are harvested by beaver and regrow from root crowns in 3-5 years; (c) a wetter and more fluvially active bottomland due to the creation and failure of individual beaver dams and ponds, elevation of groundwater by impoundments, and greater extent and power of flooding when occurring from an initially "bankfull" beaver-impounded condition.

Movement between these states may not be quickly or easily reversible. Beaver may not create physical conditions most suitable for extensive stands of tall willow without the tall willow there in sufficient amount to provide a sustainable food supply. Stands of tall (above the browse line) willow may persist (albeit in a "notched" growth form) for long periods even in a high elk, low beaver situation that would not allow seed regeneration of those stands.

DISCUSSION – STUDY PLANS

Having established replicated, controlled exclosures and initiated a series of experimental plantings, we are interested in continuing to measure responses on the time scale at which they will be ecologically meaningful and in collaborating with the Refuge in a process of iterative, adaptive restoration activity. We have gross SSP funding of $12.5k/yr through FY08. However, this work is heavily dependent on base USGS funds for permanent salaries and equipment (vehicles) that are less and less available in general and for this study in particular.

Core exclosure experiment. Maintaining exclosures so as to track willow stand response over decades is the single highest priority. We plan to resample the exclosures and controls at the end of the 2006 growing season to quantify the strength of willow stand response to release from ungulate herbivory. We have been spending a significant fraction of our resources and energy on exclosure and water recording maintenance. Responsibility and "ownership" of the permanent exclosures may have to be re-negotiated if they are to be functional for the decades necessary to observe a full stand-level response.

Based on (a) the general similarity of well water levels across transects (Fig. 2), (b) the close similarity of staff gage and "bank" well readings, and (c) the difficulty of maintaining a staff gage and recorder in the presence of large woody debris and ice, we will likely abandon the staff gages at each site, install recorders in the more stable "bank" well, and manually measure well levels less frequently (focusing on the mid-Aug. to late Sept. low water level). We also plan to continue work on detailed topographic surveying of each of the exclosure-control sites in 2006.

Restoration tests. Our approach has been "adaptive management" in the sense of iteratively trying and evaluating actions that are both feasible and hypothesized to be effective. The simple, "it-should-work-okay'" actions we have done so far have not been that successful – 2-year survivorships of plantings on the order of 10%, and effectively using volunteers in only 1 of 2 years because of inclement weather. We have not determined why simple pole planting and bank stakes are not doing better. Possible reasons include:

(a) *Plant material.* Cuttings work best when obtained as vigorously growing stems from vigorously growing plants. We have been harvesting local material largely from impoundment dikes that need to be ultimately cleared for dike maintenance. Some of this material has not been ideal, and we may not have tried the best relevant species (e.g., not yet used *Salix monticola*).
(b) *Physical conditions.* Late summer water depths and a 1 to 1.5 m decline in water levels from June to August are not ideal – while they are within the range of tolerance for adults with established root systems, they may be not be acceptable for bare cuttings establishing a new root system.

(c) *Competition.* Well-rooted established meadow vegetation may be competing effectively with cuttings for light, water, and nutrients – necessitating clearing an area around plantings.
(d) *Lack of pre-treatments and amendments.* We have not employed mycorrhizal inoculum, fertilizer, root growth hormone, extended pre-soaking, or greenhouse "starting" of cuttings.

While it would be interesting to embark on a comprehensive set of factorial experiments to isolate the factors limiting planting success, it is not feasible for 2006. Rather we propose to try another set of somewhat modified 1-m pole planting and bank stake plantings using WRV volunteers if they are able to obtain sufficient resources to be involved. Modifications will include (a) larger numbers of plantings (thousands not hundreds) with multiple poles in each hole; (b) inclusion of *S. monticola*; (c) experimentation with clearing around holes, fertilizer, and mycorrhizal amendments; and (d) more selectivity in quality of cuttings. Alternative manipulations for 2006 (especially if WRV is not able to participate) include (a) a small-scale planting of *S. monticola*, probably in combination with *S. exigua*, and *S. lasiandra*; (b) several low-cost t-post and barbed wire exclosures of suppressed willow away from the channel; (c) greenhouse experimentation with containerized cuttings; and (d) creation of some near-channel scrapped bare sites to explore potential for assisted natural seed regeneration.

Contextual analyses. We expect to continue the relative de-emphasis in this area based on available resources. In 2006, we plan to (a) conduct a series of corings to the relict channel bed (gravel layer) and do the associated surveying to provide evidence on the existence and extent of channel incision; and (b) conduct more extensive examination of mycorrhizal root colonization across species, size class, and location (hydric versus mesic). Ultimate activities might involve analysis of historic channel migration rates, longitudinal sampling of multiple drainages including densities of beaver ponds, historic air photo analyses, and hydraulic-fluvial geomorphic studies and modeling.

At a minimum, the results of the core exclosure experiment resampling in late summer of 2006 after 3 years of treatment and a 3rd year of experimental plantings in 2006 should provide a reasonable foundation for a general discussion and evaluation by Refuge management of the overall restoration strategy for riparian willow communities at Arapaho and the desired near-term tactics and actions.

CUMULATIVE DELIVERABLES

Auble, G.T., M.L. Scott, J.E. Roelle, and M. Laubhan. 2003. 2003 progress report on riparian willow restoration along the Illinois River at Arapaho NWR, Colorado. SSP03R603, unpublished. 9p.

Auble, G.T. 2004. Status of USGS-FWS willow restoration studies along the Illinois River. Technical briefing. Arapaho NWR, Walden, CO. September 7, 2004.

Auble, G.T., M.L. Scott, J.E. Roelle, and M. Laubhan. 2004. 2004 progress report on riparian willow restoration along the Illinois River at Arapaho NWR, Colorado. SSP03R603, unpublished. 5p.

Auble, G.T., J.E. Roelle, and V.B. Beauchamp. 2005. 2005 progress report on riparian willow restoration along the Illinois River at Arapaho NWR, Colorado. USGS Administrative Report, Fort Collins Science Center.

Table 1. Mycorrhizal colonization of roots from selected planted and naturally established short willows. Percentages are based on colonization at 100 locations on stained root samples. Sampling was done in September 2005 from the channel bank below bankfull elevation. Planted individuals were pole planted as part of the free-form, mixed species plantings done by volunteers.

		% Colonization		
Species	Establishment Origin	Arbuscular Mycorrhizae	Endo-mycorrhizae	Neither
Salix geyeriana	natural	34	19	47
Salix lasiandra	natural	5	8	87
Salix monticola	natural	0	0	100
S. monticola	natural	0	3	97
S. monticola	planted	0	9	91
S. monticola	planted	5	2	93
S. monticola	planted	0	10	90
S. monticola	planted	0	0	100
S. monticola	planted	0	2	98

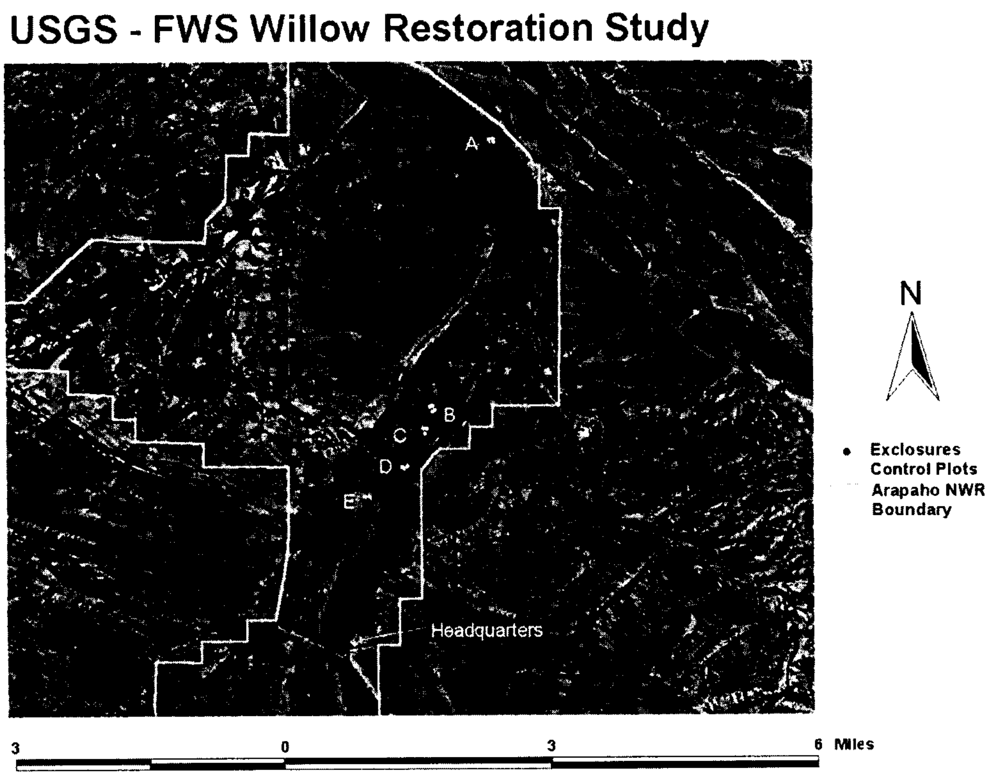


Figure 1. Location of study sites along the Illinois River in northern portion of Arapaho NWR.

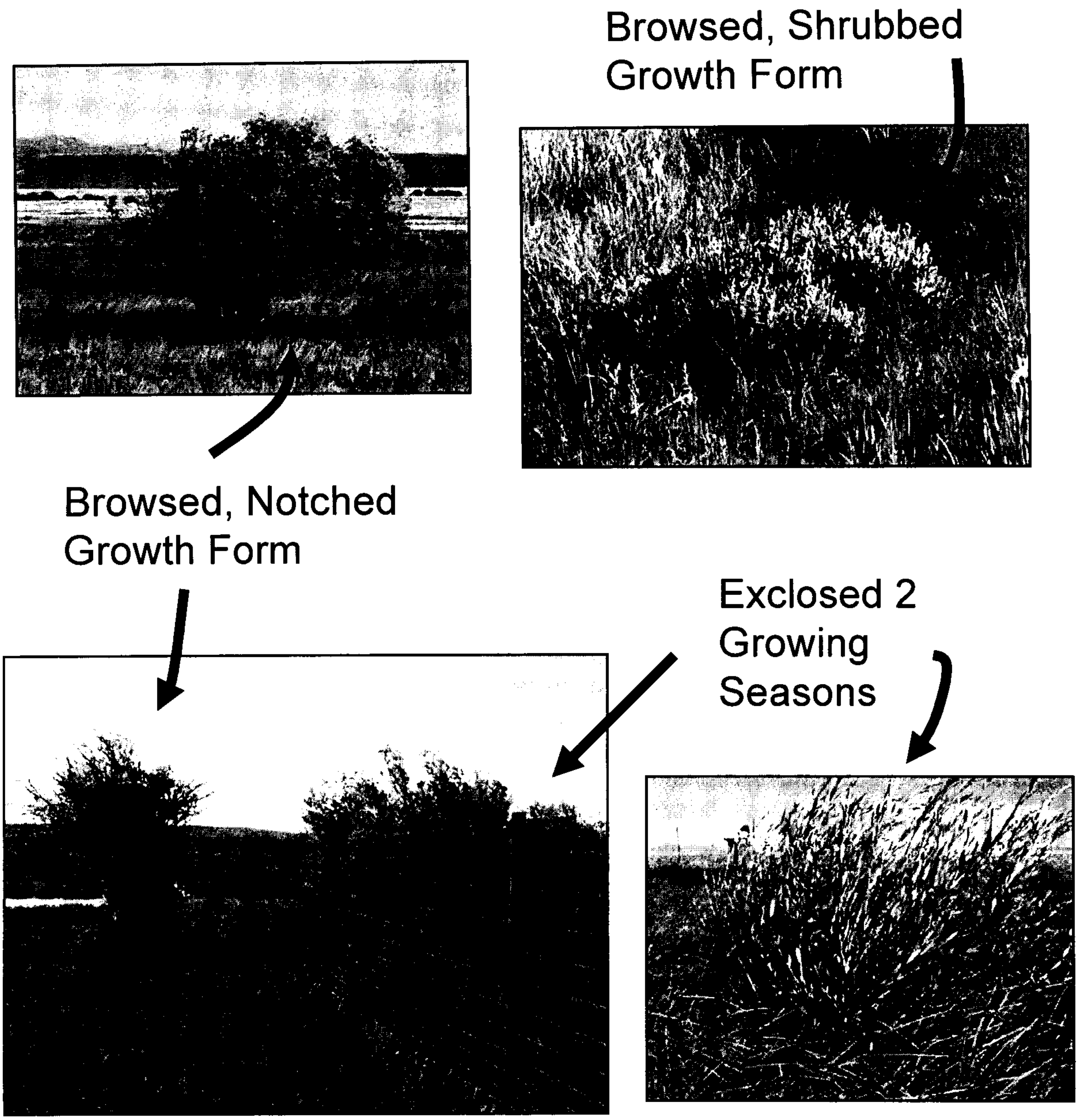


Figure 2. Individual-level examples of herbivory and exclosure effect.

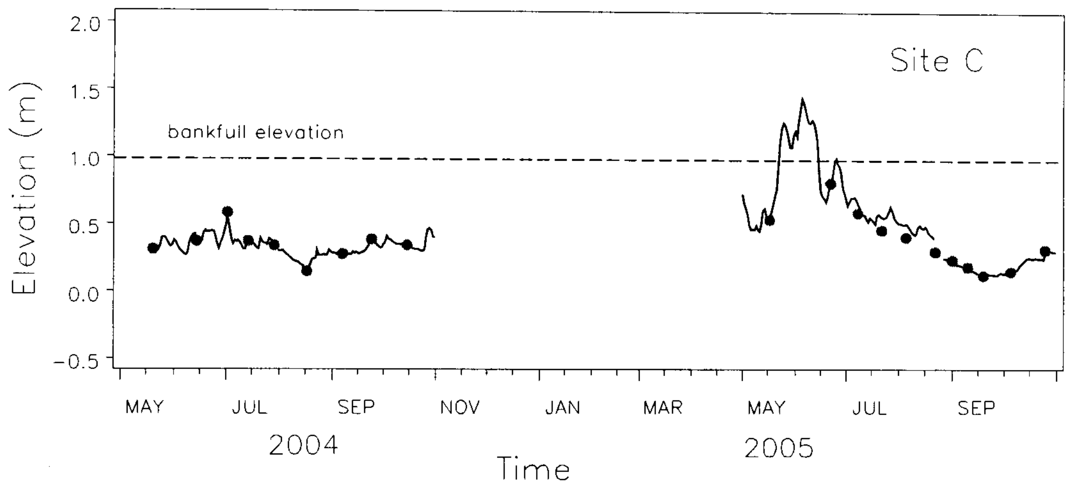


Figure 3. Water levels at Site C. Solid line is daily average level from recorder in channel. Green solid dots are levels from occasional readings of well in channel bank. Elevations are relative to local thalweg.

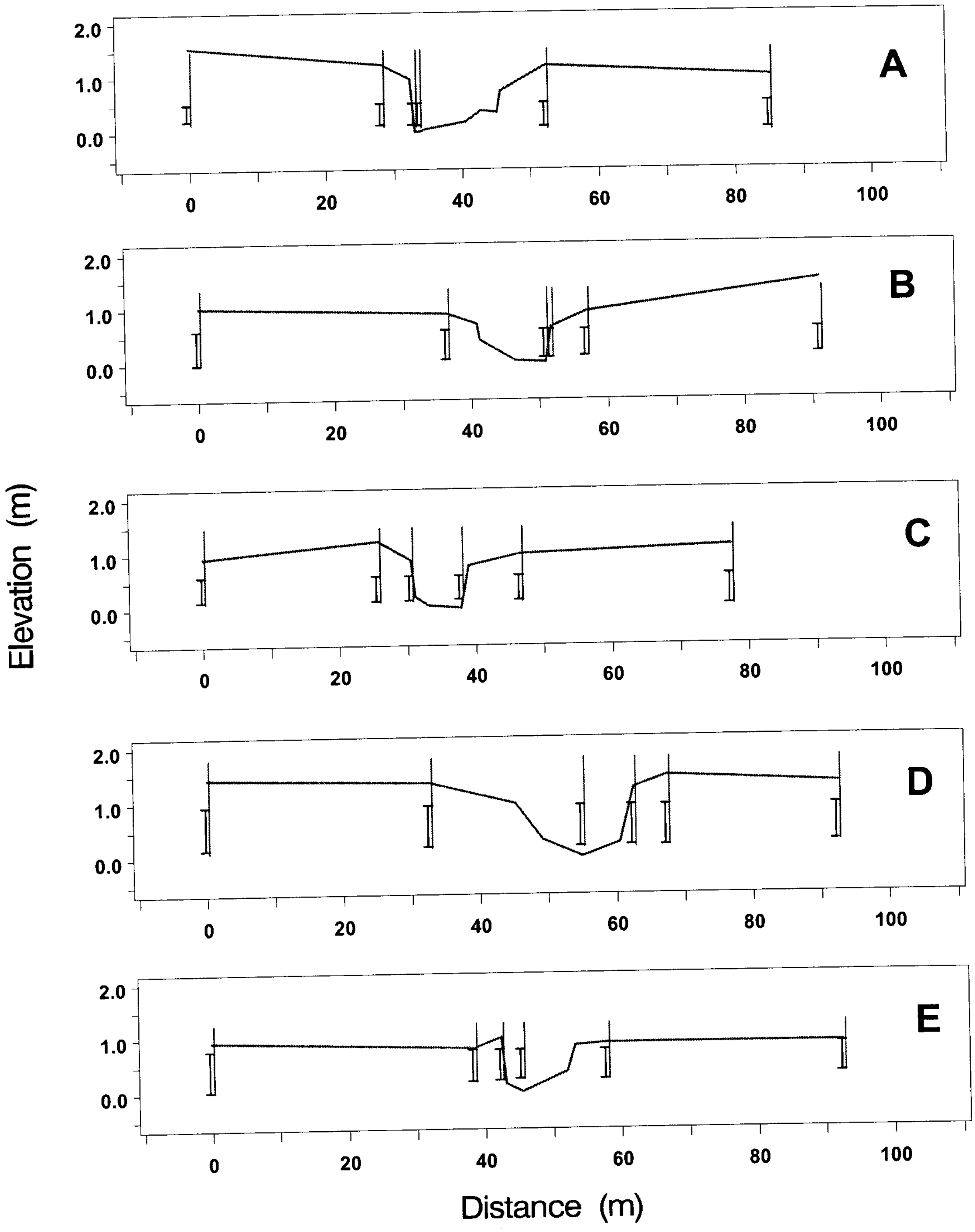
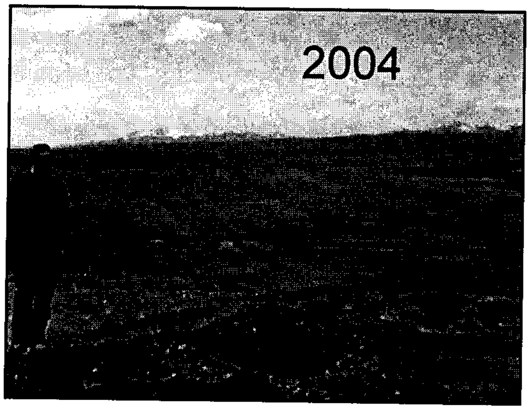
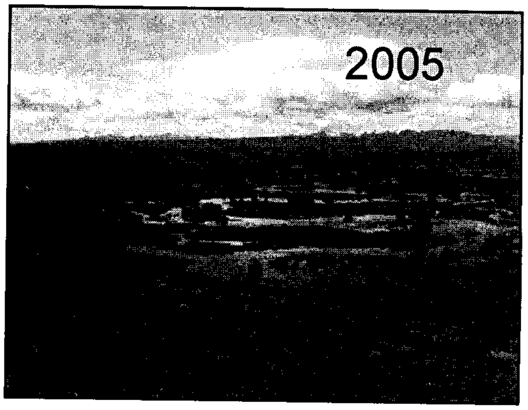


Figure 4. Water levels at cross sections. Green line is ground surface. Vertical black lines with top and bottom ticks represent minimum and maximum May-Sept. levels in 2004. Vertical blue lines are corresponding ranges for 2005. Maximum levels are estimated from channel recorder. Elevations are relative to local thalweg at each site.

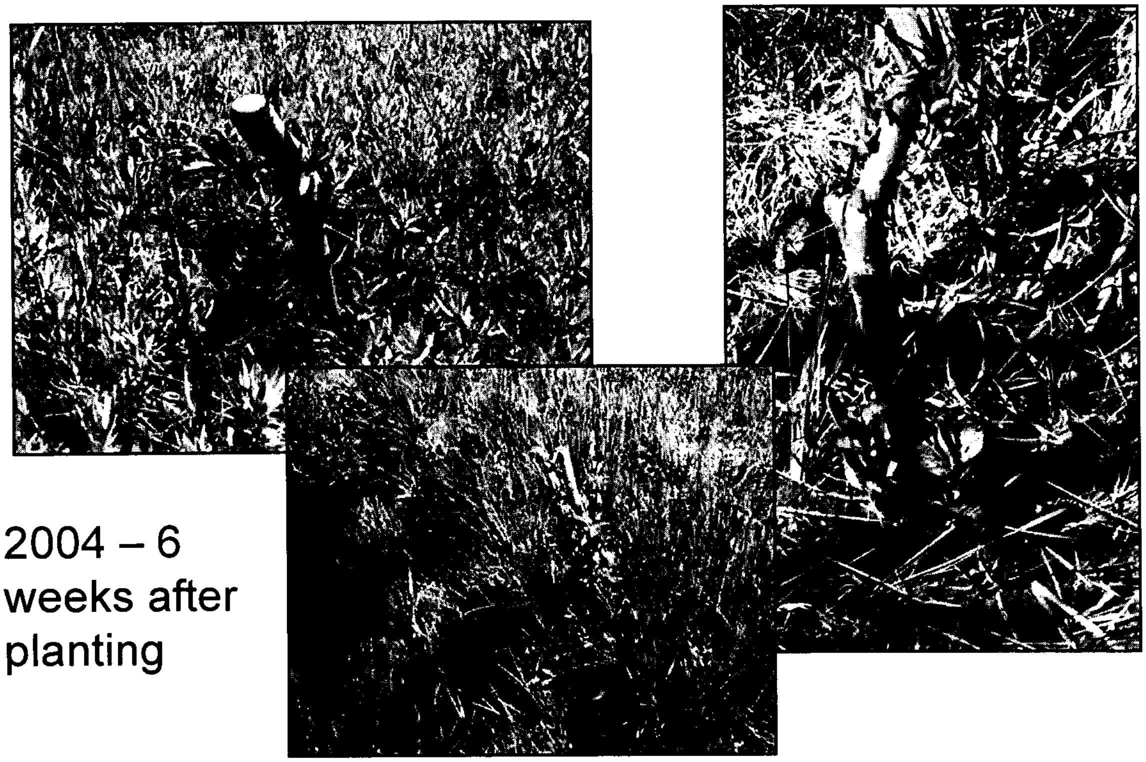
High Water





2005 Fence Damage

Figure 5. Overbank flooding in June 2005 and associated fence damage.



2004 – 6 weeks after planting

2005 – end of 2nd growing season

Figure 6. Examples of *Salix lasiandra* poles planted in May 2004.

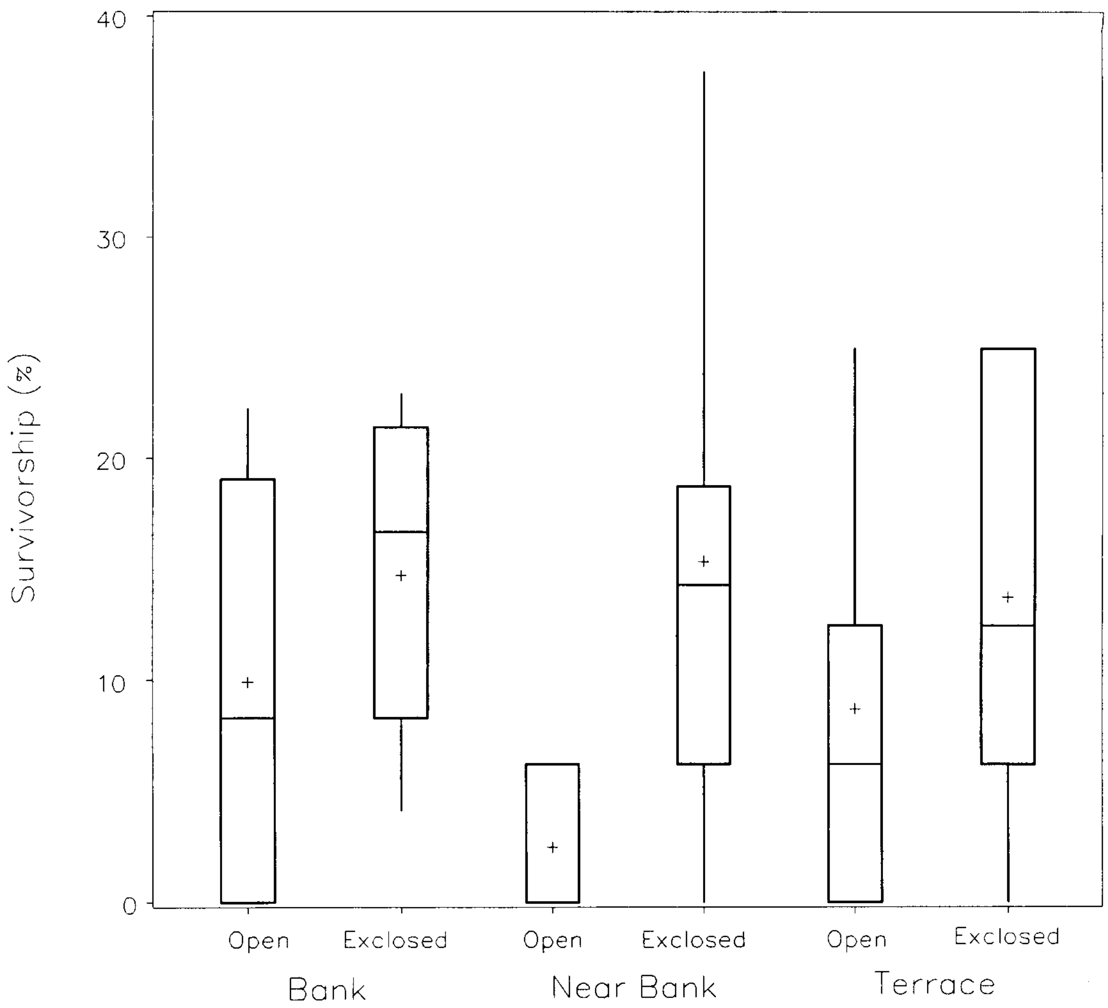
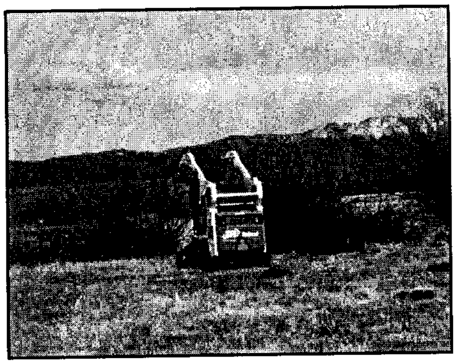


Figure 7. Survivorship of *Salix lasiandra* cuttings planted in May 2004 and sampled in Sept. 2005. Replicates (n=5) in each box plot are sites. The vertical line is the range of the data, box tops and bottoms are the 25th and 75th percentiles, the horizontal line is the median, and the plus symbol is the mean. Zones are bundles embedded in the bank (Bank), poles planted within 10 m of the bank lip (Near Bank), and poles planted more than 10 m from the bank lip (Terrace).

Planting, May 2004



Scheduled Planting, June 2005

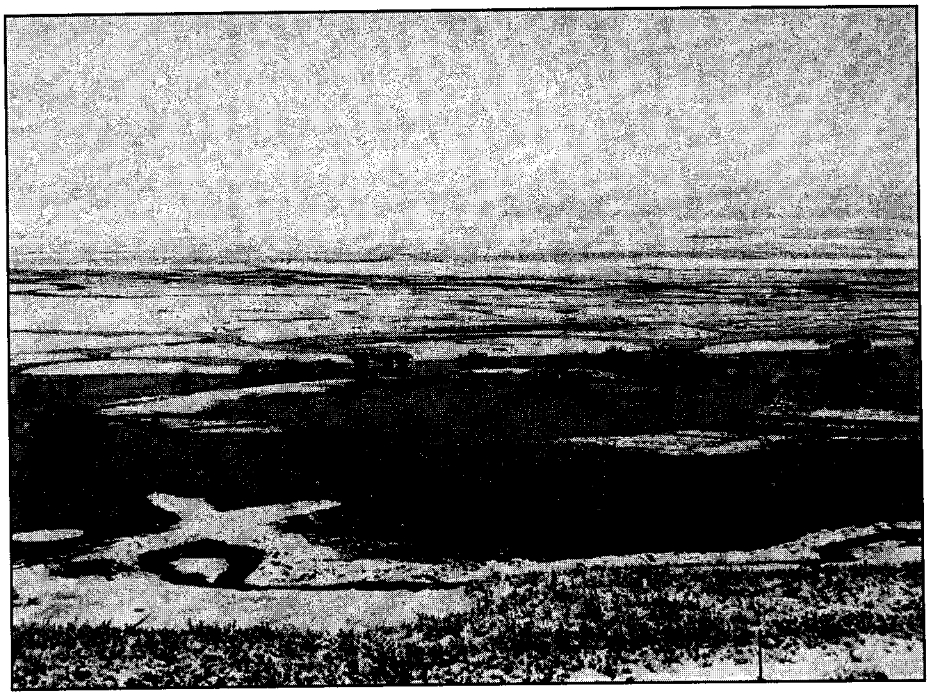


Figure 8. Inter-annual variability in spring weather at Arapaho NWR as it has affected use of volunteers in restoration activities.